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Abutment Margin Level and Residual Cement Around the Dental Implant: A Systematic Review and Meta-Analysis

ABSTRACT

Background: Excess cement around implant-supported fixed restorations is a major short-coming that can lead to implant-related and aesthetic-related problems. Different abutment marginal levels are cited as related to excess cement. *Methods:* A comprehensive search was conducted in Medline/PubMed, Scopus, Web of Science, EMBASE, and Cochrane based on the PICO strategy up to June 2023. Two authors independently screened the titles, abstracts, and full texts subsequently. The QUIN tool and Robins-I assessed the risk of bias. A random effect model was used for meta-analysis. *Results:* A total of 12 articles were included. Different abutment marginal levels including 1mm supragingival, at the gingival level, 1 mm subgingival, and 3 mm subgingival were assessed in the analysis. The combine-mean excess cement of the abutment's margins 1 mm supragingival, at the gingival level, and 1mm subgingival were 0.04 ± 0.05 ($I^2=84\%$, $CI=95\%$), 1.09 ± 2.0 ($I^2=49\%$, $CI=95\%$), and 1.18 ± 6.21 ($I^2=95\%$, $CI=95\%$), respectively. The overall proportion of excess cement in the abutment's margins of 1 mm subgingival and 3 mm subgingival level were 0.26 ($CI=95\%$, $0.21;0.3$) and 0.29 ($CI=95\%$, $0.25; 0.34$). *Conclusion:* The abutment margin level was related to residual cement. Placing the abutment margin levels more gingivally, and even supra-gingivally wherever possible, seem necessary.

INTRODUCTION

The fixed restorations supported by implants may be screw- or cement-retained. Previous studies revealed no discernible difference in the failure rate between screw-retained and cement-retained restorations.¹⁻³ Other circumstances determine whether to choose screw or cement-retained restorations.^{4,5} In everyday practice, cement-retained restorations are preferred, probably because dentists are better accustomed to them.⁶ Cement-retained restorations have better esthetic, as they do not contain screw access holes, and are easier to fabricate in lab, which lowers costs.^{4,7-9}

A significant drawback of cement-retained restorations is the undetected residual cement that can function as "artificial calculus", creating an oral microbial habitat⁷ and contributing to late implant failure.^{10,11} There is less resistance to pressure since the fibers in the soft tissue around the dental implant are positioned parallel to the implant surface. It might cause residual cement to be forced further apically, where it is impossible to detect or remove. This excess cement is hauled up concerning the abutment margin's vertical position.¹² To lessen this drawback of cement-retained restorations, some alternatives, including the fabrication of more coronally

placed customized abutments, the provision of a venting hole, and the use of different removal techniques, such as plastic scalers, are proposed.^{8,13-15}

The shape, size, and height of the abutments affect the success rate of implant restorations.^{16,17} There is presently no systematic review measuring the quantity of excess cement at different abutment height levels, despite the fact that placing the abutment height more gingivally can complicate the cleaning of excess cement.¹⁸ This systematic review and meta-analysis aim to assess different abutment margin levels and how they affect the amount of residual cement around cement-retained dental implant restorations in standard and individualized CAD/CAM implant abutments.

MATERIALS AND METHODS

PROTOCOL AND REGISTRATION

This review is reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.¹⁹ The protocol of this review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42023437182).²⁰

SEARCH STRATEGY

In June 2023, a bibliographic search was carried out in Medline/PubMed, Scopus, Web of Science, EMBASE, and Cochrane using the search strategy shown in Table 1.

PICO QUESTION

The following Population, Intervention, Comparison, Outcome (PICO) framework was applied to the study’s aimed question:

- Population (P): Patients treated with cement-retained, implant-supported restorations.
- Intervention (I): Placement of abutment margins at various vertical levels, including supragingival, equigingival (at the gingival margin), and subgingival depths.
- Comparison (C): Comparisons between the defined abutment margin levels, taking into account the study type (clinical vs. *in vitro*) and implant location (maxillary vs. mandibular; anterior vs. posterior).
- Outcome (O): The quantity of residual cement surrounding the dental implant restorations.

ELIGIBILITY CRITERIA

Controlled trials, prospective trials with historical controls, prospective or retrospective cohort studies, and case series involving more than four patients are all considered as primary studies. Review studies, case reports, commentaries, and letters to the editor were excluded from the study. No time or language restrictions were applied.

Table 1. Search strategy.

Search strategy	Database
(“Dental Abutments”[Mesh]) OR (((“dental implant”[Title/Abstract]) OR (“dental prosthesis”[Title/Abstract])) OR (abutment[Title/Abstract])) AND (“Dental Cements”[Mesh] OR (Cement[Title/Abstract]))	Medline/ PubMed
(TS=(“Dental Abutments”) OR TS=(“dental implant”) OR TS=(“dental prosthesis”) OR TS=(“abutment”)) AND (TS=(“Dental Cements”) OR TS=(“Cement”))	Web of Science
ID Search #1 MeSH descriptor: [Dental Abutments] explode all trees #2 (“dental implant”): ti,ab,kw #3 (“dental prosthesis”): ti,ab,kw #4 (abutment): ti,ab,kw #5 MeSH descriptor: [Dental Cements] explode all trees #6 (Cement): ti,ab,kw #7 residual #8 (#1 or #2 or #3 or #4) and (#5 or #6)	Cochrane
(“Dental Abutments”/exp OR “Dental Abutments”) OR (“dental implant”:ti,ab OR “dental prosthesis”:ti,ab) OR “abutment”:ti,ab) AND (“Dental Cements”/ exp OR “Dental Cements”) OR “Cement”:ti,ab)	Embase
TITLE-ABS (“dental abutments” OR “dental implants” OR “dental prosthesis” OR “abutment” OR “dental abutment”) AND TITLE-ABS (“dental cement” OR “cement” OR “Dental Adhesives” OR “luting agent” OR “luting agents”)	Scopus

SELECTION OF STUDIES

After eliminating duplicates, the Rayyan website was used to manage article.²¹ Two researchers (S.M., A.T.) independently screened articles by evaluating titles and abstracts for appropriateness and the inclusion of the selection criteria. Retrieved records were classified as include, exclude, or maybe. The same two reviewers examined the full-text articles of included and questionable records for a final conclusion. Discrepancies were resolved through discussion between the two reviewers. In the case of disagreements, a third investigator (A.M.) made the ultimate decision.

DATA EXTRACTION

The focus of the research question guided the selection of studies. Full-text articles were surveyed independently by two reviewers (S.M., and A.M.) and the following data were extracted: study design, Number of patients, Number of implants,

Abutment type, Restoration type, Cement type, Excess cement removal method, Excess cement detection method, excess cement, abutment margin level and the region of the implant. The additional data was acquired by contacting the study's authors through their e-mail addresses if necessary. According to the abutment height, the excess cement was divided into three categories: "excess cement in supragingival abutment margin level", "at soft tissue margin level excess cement", and "excess cement in subgingival abutment margin level". The amount of excess cement was extracted based on the location (divided into mesial, distal, buccal, and lingual/palatal aspects).

QUALITY ASSESSMENT

Two evaluators (A.M., and A.B.) independently assessed the risk of bias for each study included in the analysis. They evaluated *in vitro* experiments using the QUIN tool²² and Robins-I for the rest of the included studies.²³ The key domains that were assessed were (1) randomization process, (2) allocation concealment, (3) outcome assessment blinding, (4) data outcome assessment, (5) bias in reporting, and (6) other bias. When there were conflicts, the authors reached a consensus through discussion. A third author (A.T.) was consulted to settle any remaining disputes if necessary. According to the guidelines of each tool utilized, the final judgment criteria for evaluating studies were classified as: "High", "moderate", "low", and "unclear" risk of bias.

STATISTICAL ANALYSIS

The statistical analysis was made by the Meta package of R version 4.3.1. Combine the prevalence and mean of studies and conclude the pooled prevalence, mean, and 95% confidence interval (CI). Forest plots were drawn to illustrate the variation of the mean and prevalence among all studies, together with the pooled measure. Cochran's Q test and the I^2 statistic were used for Between-study heterogeneity. The random effect model was used for $I^2 > 50\%$ or $p < 0.05$. Egger's and Begg's tests were used to detect publication bias.

RESULTS

STUDY SELECTION

Running the search strategy initially led to 5355 articles. After removing duplicates, checking the relevancy of titles and abstracts, and reviewing the full texts, 12 articles were included and reported in the study. Among the extracted variables, nine were capable of meta-analysis. The study selection process was systematically documented and presented using the PRISMA flow diagram chart, as shown in Figure 1. The inter-reviewer reliability was 99% in the screening and inclusion process.

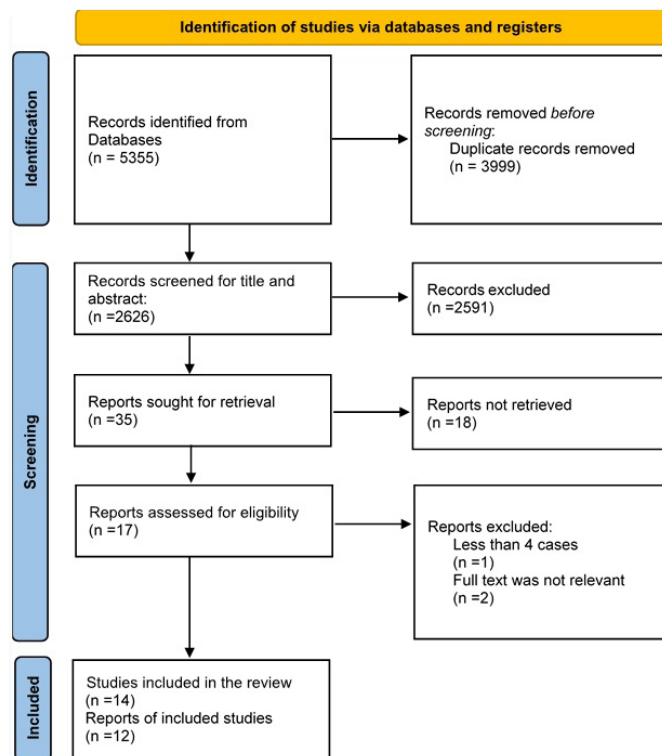


Figure 1: The inter-reviewer reliability in the inclusion was 99% in the screening and inclusion process.

STUDIES CHARACTERISTICS

Based on a comprehensive review of pertinent studies, assessing 12 studies carried out from 2011 to 2023 (Table 2),^{6-8,12,15,18,24-29} Two additional studies were incorporated into the qualitative analysis of the systematic review; however, their data were not extracted due to substantial heterogeneity in their datasets.^{30,31} The sample sizes ranged from 20 to 109 for each study. The variation in samples within the forest plot meta-analysis is due to the studies being classified into relevant subgroups based on the level of abutment margin, with the meta-analysis subsequently conducted on the corresponding subgroups. These subgroups were selected based on specific characteristics related to abutment geometry (With a vertical groove (VG), With one horizontal groove (1HG), With two horizontal grooves (2HG), Without any geometrical change (WGC)), cement type (Zinc oxide non-eugenol cement (ZONE) Methacrylate cement (META)), abutment type (Standard abutment (SA), Individualized abutment (IA)), crown venting (Only None vented crown (NV) subgroup was included. In contrast, the vented crown subgroup was excluded due to the cleaning action being removed), cement removal methods (Subgroup not using PEEK Tips (NPK): This subgroup utilized traditional methods for cement removal, including a stainless-steel explorer, plastic curettes, and super-floss, but did not use PEEK (Poly-ether-ether-ketone) Tips. Subgroup using PEEK Tips (PK): In addition to the standard cement removal tools (stainless-steel explorer, plastic curettes, and super-floss), this subgroup also used PEEK (Poly-ether-ether-ketone) Tips to remove excess cement.), and detection techniques (Detection using photographic data number of pixels analysis (P)). According to the methodologies

Table 2. Study characteristics.

REF NO.	Author	Year	Study type	NO. of patients	NO. of implants	Abutment type	Material	Cement type	Remove method	Assessment method for residual cement	Margin depth (mm)	Implant Site and Location
1	HJ.Kim et al. ¹²	2022	Observational	103	109	Customized abutments	Titanium, zirconia	Resin-modified glass-ionomer cement	Dental Explorer, wax-coated dental floss	Photographic data	supra, 0, -0.5, ≥1 mm subgingivally	Maxilla Mandible
2	P. Gehrke et al. ²⁷	2019	In-vitro		20	CAD/CAM implant abutments	Titanium	Zinc oxide non-eugenol cement, methacrylate cement	Acrylic scaler	Photographic data, number of pixels analysis	0, -1, -2, -3	left maxillary first molar
3	T.Linkevicius et al. ²⁶	2012	Prospective clinical study	53	53	Standard abutments	NI	Resin-modified glass-ionomer cement	Stainless steel explorer + dental floss + super-floss	Photographic data, number of pixels analysis of all four aspects	0, -1, -2, -3	Maxilla Mandible
4	T.Linkevicius et al. ¹⁸	2011	In-vitro		25	Implant analogs	NI	Resin-modified glass-ionomer cement	Stainless steel explorer + super-floss	Weigh the cement remnants removed from each specimen / photographic data, number of pixels analysis	1, 0, -1, -2, -3	Maxillary central incisor
5	M. Sancho-Puchades et al. ⁷	2017	In-vitro		60	CAD/CAM implant abutments	Zirconia	Resin cement	Foam pellets	Stained with eosin/ photographic data / Area of residual cement (mm ²)	0, -1.5, -3	Maxillary central incisor
6	CZ.Koyuncuoglu et al. ⁶	2020	In-vitro		32	Standard abutments	Titanium	Methacrylate cement	Stainless-steel explorer + plastic curettes + super-floss / PEEK(Poly-ether-ether-ketone) Tips	Photographic data/number of pixels	-1, -2,5, -3, -4	Maxillary central incisor
7	KW.Hsu et al. ²⁹	2022	Preliminary cohort	80	80	custom abutment	Zirconia, Titanium	Resin-modified glass ionomer, resin cement	Stainless-steel explorer + dental floss + pressurized / mixture of air and water	Photographic data / Area of residual cement (mm ²)	-1	Maxilla/ mandible
8	G.wasiluk et al. ²⁵	2016	Prospective case series	34	60	customized CAD/CAM abutments	Titanium	Glass ionomer cement	Dental explorer and dental floss	Dichotomous evaluation of the cement presence/absence on the crown/abutment unit	-1	Premolar, Molar/maxilla, mandible
9	F.wang et al. ²⁸	2023	In-vitro		40	Implant analogs	NI	Dual-curing resin cement	Stainless-steel explorer + rinsing the debris with saline and air-spray	Photographic data / Area of residual cement(mm ²) / ImageJ software	-1(Buc, Mes, Dis), 0(Pa)	Right maxillary first molar
10	S. Kappel et al. ¹⁵	2015	Prospective randomized pilot trial	20	20	Standard/ individualized abutment	Zirconia	Glass ionomer cement	Plastic curettes + dental floss + super floss	Photographic data /ratio of the area coated with cement to the total surface area of the crown	0-1 Mes, Dis, Pal / -1 Buc	NI
11	R.Negahdari et al. ⁸	2021	In-vitro		72	Straight abutments	NI	Temp-Bond™ NE	Plastic scaler	Weigh coping/abutment/analog/acrylic block before and after cement removal	1 (gingival height)	NI
12	ZG.Yue et al. ²⁴	2021	In-vitro	1	20	customized abutments/ stock abutment	Titanium	Resin-modified glass ionomer cement	Dental probe + dental floss	Photographic data/area proportion of residual cement / the volume of residual cement by a 3D scanning technique/weight by analytical balance	1,3,4,5 (transmucosal height)	Maxillary right central incisor

used in investigations, seven studies were utilized in the *in-vitro* approach.^{6,8,18,24,27,28} Others were used in observational designs, prospective clinical study, preliminary cohort, prospective case series, and prospective randomized pilot trial.^{12,15,25,26,29} According to the study languages, one study was Chinese,²⁴ and the others were English. Notable findings included a more significant occurrence of cement remnants in subgingival margins, the influence of alterations in the abutment's shape and material in reducing residual excess cement, and the efficacy of different cleaning procedures.

RISK OF BIAS ASSESSMENT OF INCLUDED STUDIES

A comprehensive evaluation was conducted to assess the quality and bias present in the included studies. The outcomes of this evaluation are presented in Figure 2A, where each study was given a score based on specific criteria. The assessments indicate moderate levels of overall risk of bias among these studies; however, there are instances of moderate bias in the category of missing data bias¹² and selection of the reported result bias.^{15,25,26,29,31} For *in-vitro* studies, Scores

ranging from 0 to 2 were given to each criterion for all *in-vitro* studies and then summed to derive the final score of the QUIN risk of bias assessment. The outcome of this thorough assessment is also presented in Figure 2B.

RESULTS OF META-ANALYSIS

Combine-Mean of the Excess Cement of the Abutment's Margins 1 mm Superior to the Gingival Level

The meta-analysis was conducted on four subgroups of R. Negahdari *et al.*,⁸ with a total of 72 observations, where the abutment geometry was altered as follows: 1. with vertical groove (VG), 2. with one horizontal groove (1HG), 3. with two horizontal grooves (2HG), and 4. without any geometrical change (WGC). However, the margin was located 1 mm superior for all subgroups. The random effect size yielded an overall effect size estimate of 0.04 with a 95% CI [0.04; 0.05]. The heterogeneity analysis indicated a significant heterogeneity among the included subgroups ($I^2 = 84%$) (Figure 3A). The test of heterogeneity (Q-test) was statistically significant ($p < 0.0001$). The funnel plot

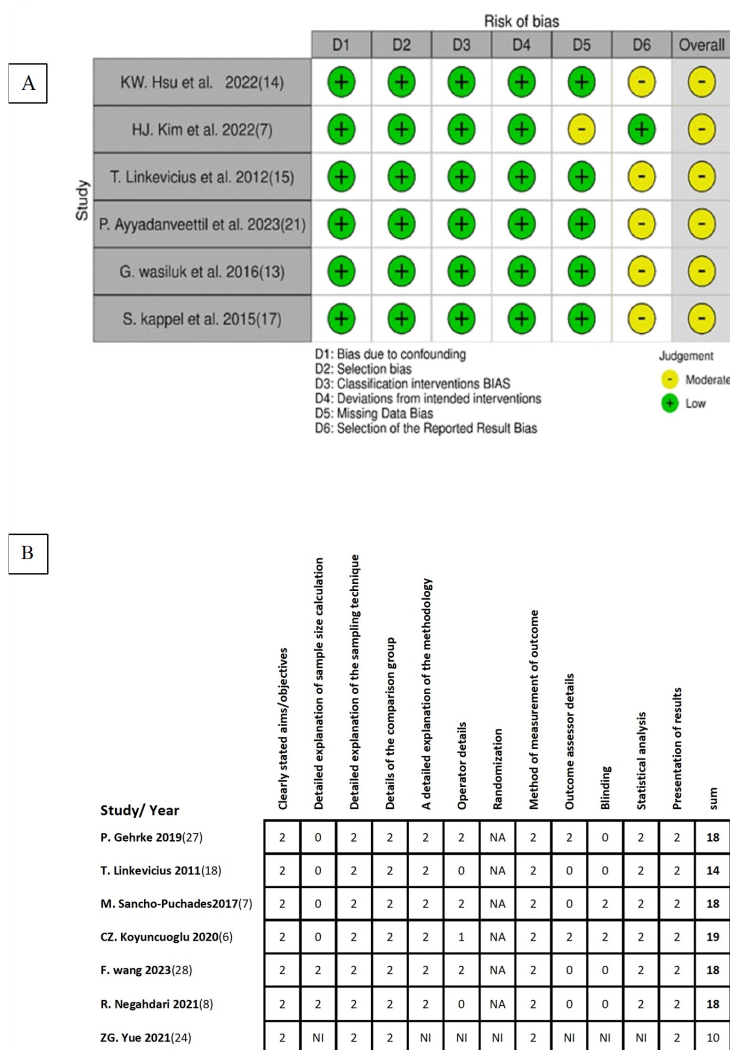


Figure 2: A: ROBINS-I bias assessment of in-vivo studies. B: Risk of bias assessment of IN-VITRO studies, NI: Not Included, NA: Not Applicable.

analysis showed a symmetrical distribution of four subgroups. The results of both Egger's test ($p = 0.14$) and Begg's test ($p = 0.17$) didn't show publication bias in the included studies (Figure 3B). Sensitivity analysis showed that the excluded studies didn't significantly impact the total mean estimate of excess cement of abutment's margins 1 mm superior to the gingival level(s) (Figure 3C).

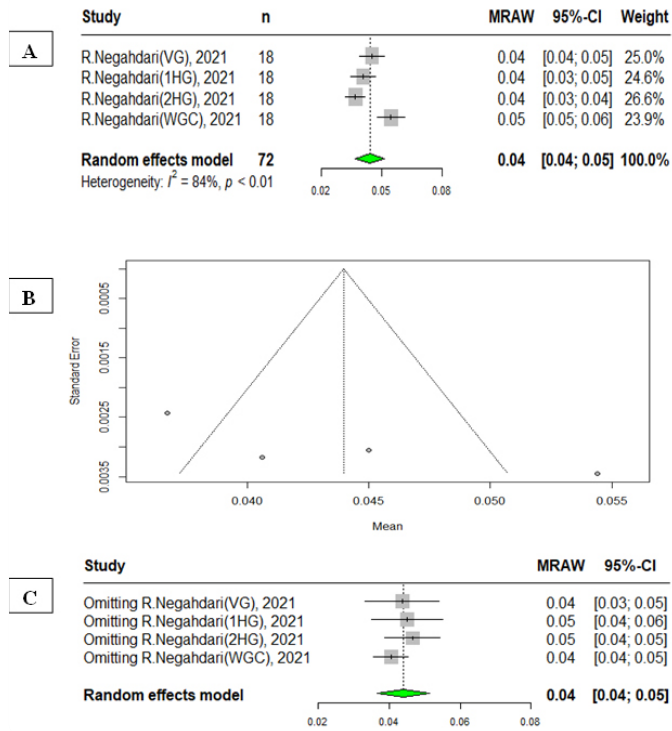


Figure 3: A: Forest Plot of Random Effect Model of excess cement of abutment's margins 1mm superior to the gingival level; B: Funnel Plot Analysis; C: Sensitivity Analysis; (VG: Vertical Groove/ 1HG: One Horizontal Groove/ 2HG: Two Horizontal Grooves/ WGC: Without Geometrical Change/ MRAW: Mean Raw Effect Size).

Combine-Mean and Prevalence of Excess Cement of Abutment's Margins at the Gingival Level

In the meta-analysis of abutment margins at the gingival level reported in percentage in P. Gehrke's study,²⁷ two subgroups were defined based on the cement type: 1. zinc oxide non-eugenol cement (ZONE) and 2. methacrylate cement (META), and in S. Kapple's study,¹⁵ the subgroups were based on the abutment type used in the study: standard abutment (SA) or individualized abutment (IA). For these two studies,^{15,27} the fixed effects model estimated a mean effect size of 1.54 with a 95% CI [1.09; 2.00] (Figure 4A). The analysis did not indicate heterogeneity ($I^2 = 49\%$).

The test of heterogeneity (Q-test) was not statistically significant ($p = 0.12$). The funnel plot analysis showed a symmetrical distribution of studies. The results of both Egger's test ($p = 0.75$) and Begg's test ($p = 0.49$) didn't show publication bias in the included studies (Figure 4B).

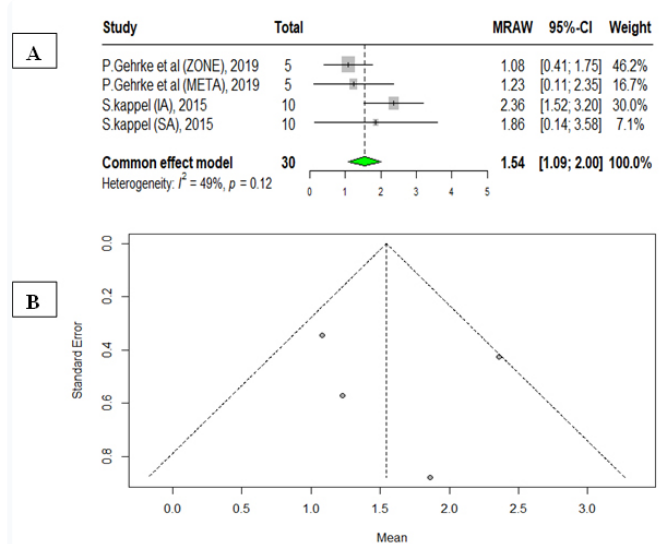


Figure 4: A: Forest Plot of Fixed-Effect Model of abutment margins at the gingival level; B: Funnel Plot Analysis; (ZONE: Zinc Oxide Non-Eugenol Cement/META: Methacrylate Cement/ SA: Standard Abutment /IA: Individualized Abutment/ MRAW: Mean Raw Effect Size).

In the meta-analysis of the combined mean excess cement of abutment margins at the gingival level reported in mm², two subgroups were used for analysis based on the abutment profile in M. Sancho-Puchades' study (7): 1. Concave (CC) and 2. Convex (CV). In F. Wang's study,²⁸ the non-vented crown (NV) subgroup was included in the analysis, while the vented crown subgroup was excluded from this process because of the removal of the cleaning action. In ZG. In Yue's study,²⁴ subgroups of customized abutments with 5 mm transmucosal height (5TH) were used for the analysis. The random effects model estimated a mean effect size of 3.70 with a 95% CI [1.18; 6.21] (Figure 5A). The analysis indicated substantial heterogeneity among the included studies ($I^2 = 95\%$). Q-test shows significant heterogeneity among the included studies ($p < 0.01$). The results of both Egger's test ($p = 0.16$) and Begg's test ($p = 0.50$) didn't show publication bias in the included studies (Figure 5B). Sensitivity analysis showed that the excluded studies didn't have a statistically significant impact on the total mean estimate of excess cement of abutment's margins at the gingival level(s) (Figure 5C).

According to H.J. Kim¹² and S.Kapple¹⁵ studies, the meta-analysis included 516 observations and 327 events. The random effects model analysis yielded an estimated proportion of 0.55 with a 95% CI [0.36; 0.74]. The analysis indicated substantial heterogeneity among the included studies ($I^2 = 88.9\%$). The test of heterogeneity was statistically significant ($p < 0.01$) (Figure 6A).

Prevalence of Excess Cement of the Abutment's Margins at 1 mm Subgingival Level

The meta-analysis comprises 365 observations and 93 events, as reported in the studies by T. Linkevicius^{18,26} and C.Z. Koyuncuoglu.⁶ In C.Z. Koyuncuoglu's study,⁶ there were

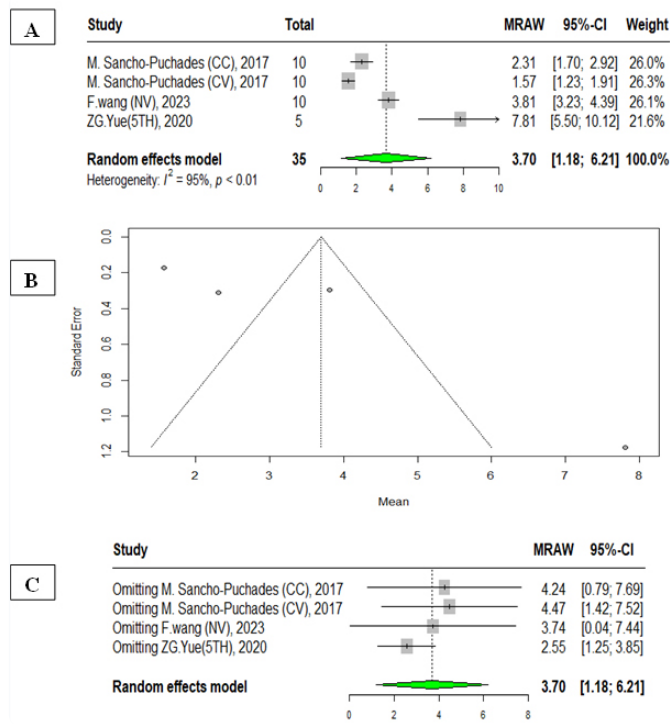


Figure 5: A: Forest Plot of Fixed-Effect Model analysis of the combined mean excess cement of abutment margins at the gingival level; B: Funnel Plot Analysis; C: Sensitivity Analysis; (CC: Concave abutment profile/ CV: Convex abutment profile/ NV: None vented crowns/ 5TH: Customized abutments with a 5 mm transmucosal height/ MRAW: Mean Raw Effect Size).

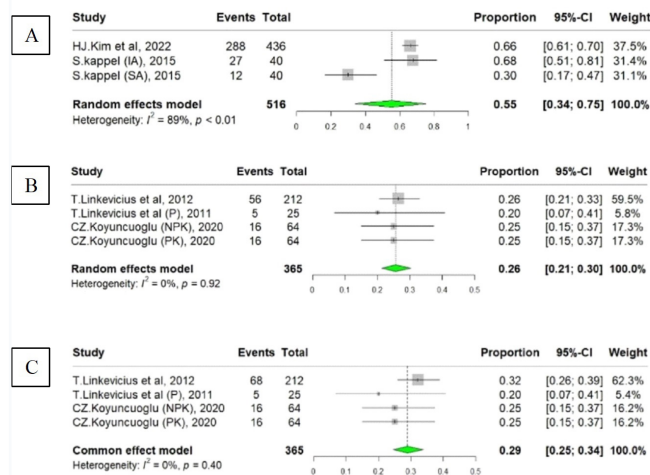


Figure 6: A: Forest plot analysis of the prevalence of excess cement of abutment margins at the gingival level; (IA: Individualized/ SA: Standard); B: Forest plot analysis of the prevalence of excess cement of abutment margins at 1mm subgingival level; C: Forest plot analysis of the prevalence of excess cement of abutment margins at 3mm subgingival level; (P: Photographic data number of pixels used for analysis/ PK: Poly-ether-ether-ketone removal tools/ NPK: Poly-ether-ether-ketone not used for cement removal/ MRAW: Mean Raw Effect Size).

2 subgroups, one of which utilized an additional method for removing cement. In addition to the stainless-steel explorer, plastic curettes, and super-floss, another group used PEEK (Poly-ether-ether-ketone) Tips for cement removal (PK). In T. Linkevicius's study,¹⁸ there were two subgroups divided by the method used to detect excess cement. One group was detected using photographic data and number of pixels analysis (P), while the other group used the weight of the cement remnants removed from each specimen. Only the photographic-detected group was included in the analysis. The random effects model estimates the overall proportion to be 0.26, with a 95% CI [0.21; 0.30] (Figure 6B). The heterogeneity analysis suggests no significant heterogeneity ($I^2 = 0\%$). The heterogeneity test suggests no considerable heterogeneity among the included studies ($p = 0.92$).

Prevalence of Excess Cement of the Abutment's Margins at 3 mm Subgingival Level

Based on the meta-analysis conducted for the studies by T. Linkevicius *et al.*^{18,26} and C.Z. Koyuncuoglu *et al.*⁶ a total of 365 observations and 365 events were included. The fixed effects model analysis resulted in an estimated proportion of 0.29, with a 95% CI [0.25; 0.34]. The analysis did not indicate heterogeneity ($I^2 = 0\%$). The test of heterogeneity (Q-test) was not statistically significant ($p = 0.40$) (Figure 6C).

DISCUSSION

This systematic review and meta-analysis aimed to evaluate the influence of different abutment margin levels on residual cement around cement-retained dental implants. The results indicated a statistically significant relationship between the quantity of undetected cement after cleaning and the marginal abutment level.

Three studies evaluated the excess cement in 1 mm supragingival abutment marginal level,^{8,12,18} one of which was *in vivo*. As our meta-analysis on R. Negahdari *et al.*⁸ demonstrated, marginal levels placed supragingivally resulted in the lowest amount of excess cement. The excess cement at the gingival level abutment height was documented in eight studies.^{7,12,15,18,24,26-28} The meta-analysis concluded that even after meticulous cleaning and inspection, cement remnants will be found in all abutment margins placed at the gingiva, and excess cement is an inevitable component of this. Among all the research that reported results in mm², Wang *et al.*²⁸ weighted cement and had a defined amount of cement. Yue *et al.*²⁴ reported the most significant amount of residual cement at the gingival level in mm². That might be the result of different techniques for detecting excess cement. They employed a 3D scan, a novel method of detection. Five studies evaluated abutment marginal level at 1 mm subgingival^{6,18, 26,27,29} and the prevalence of excess cement was slightly lower at 1 mm subgingivally placed marginal level compared to the gingival level of the abutment's margin. All studies that provided proportional data at the gingival level were *in vivo*, whereas studies reporting

the results of abutment marginal level at 1 mm subgingival were *in vitro*, except for Linkevicius *et al.*,²⁶ which may explain the reduction observed in cement remnants at subgingival levels. The detection method of residual cement was the same among studies placing the marginal level 1 mm subgingivally, using photography and Adobe Photoshop. This uniform technique may be another reason for this result.

Five studies evaluated the excess cement in 3 mm subgingival abutment marginal level,^{6,7,18,26,27} and all used photographic data analysis to evaluate excess cement. The Linkevicius's study²⁶ was *in vivo* and showed more excess cement as the residual cement was not accessible. The difficulty in accessing and cleaning margins placed more than 2 mm subgingivally was a common finding in many studies.^{18,25-27,31} Our meta-analysis was consistent with these studies, showing an increase in the proportion of residual cement at the 3 mm marginal level compared to the 1 mm marginal level.

There were conflicting opinions about the effect of different dental surfaces on the amount of residual cement. Wang *et al.*²⁸ reported more excess cement in the distal area and the least amount in the lingual part of the abutment, which was considered to be related to its different height. In Kim *et al.*¹² study, interproximal areas showed more excess cement, and the amount of residual cement on the mesial surface was the highest. Sancho-Puchades *et al.*⁷ showed that cleaning was more difficult on all dental surfaces except the buccal surface, which was more accessible and visible. They reported higher amounts of residual cement on interproximal surfaces. Hsu *et al.*²⁹ showed more excess cement on interproximal surfaces, but it wasn't statistically different from the amount of excess cement on the buccal/lingual surfaces. The same results were found in Gehrke *et al.*,²⁷ showing that the amount of excess cement was higher in the distal area without being statistically different from other surfaces. In Kappel *et al.*¹⁵ study, placing the buccal margin subgingivally due to esthetics, showed more excess cement in the buccal area, which wasn't statistically significant. This indicates that paying attention to interproximal areas and marginal levels placed subgingivally is crucial.

The type of cement may affect the amount of residual cement. Wang *et al.*²⁸ reported the complexity of removing the cement remnants after the completion of cementation. In the Ayyadanveetil *et al.*³¹ study, resin excess cement was the highest due to its translucency and lower flowability. These results are consistent with the results of the other studies, indicating that resin cements in cement-retained restorations require special considerations regarding the removal of excess cement.^{28,32} On the other hand, Hsu *et al.*²⁹ and Gehrke *et al.*²⁷ didn't report any statistically significant relationship between the types of cement and the amount of residual cement. Wilson *et al.*³³ showed that more than 80% of peri-implant diseases were caused by residual cement, and removing the residual cement led to the elimination of peri-implant disease signs in 76% of the patients. Nematollahi *et al.*¹⁴ prioritized choosing temporary cement where retrievability was a concern and recommended resin cement

where retentivity was an issue.^{14,34} Sulcus fluids could wash out conventional cements like ZONE, resulting in the exhibition of less excess cement over time.³⁵ Any cement has special removal instructions, affecting the amount of residual cement after complete cleaning. Some types of cement, like Glass ionomer cement (GIC), must be removed only after curing, and some could be removed before or after curing, like Resin-modified glass ionomer cement (RMGIC).³⁴

Differences between gingival mask and gingiva are another concept that should be discussed. As mentioned in Linkevicius *et al.*^{18,26} and Wang *et al.*,²⁸ no excess cement was found on the gingival mask; if it was, it could be removed easily. Sancho-Puchades *et al.* showed that the gingival mask drew back some excess cement in the convex profile that may not be seen in the gingiva. Hsu *et al.*²⁹ reported that observing more residual cement has a higher probability considering the clinical conditions of the gingiva. These differences can be seen in our meta-analysis, in which *in vitro* studies showed lower amounts of excess cement compared to *in vivo* ones at the same marginal levels. As Greenstein *et al.*³⁶ mentioned, soft tissues surrounding subgingivally-placed dental restorations were more susceptible to inflammation, explained by different types of fibers and connecting structures. The cement remnants can act as artificial calculus and provide a suitable situation to form an inflammation. In implant restorations unlike teeth, a small amount of recession is considered an esthetic failure, in which exposing the surface of the fixture causes a vicious cycle of biofilm accumulation and inflammation.^{7,36,37}

Cementing the restoration in the mandible or maxilla may lead to different amounts of excess cement. Wasiluk *et al.*²⁵ reported more excess cement in the mandible and posterior regions, without being statistically significant. Kim *et al.*¹² and Kappel *et al.*¹⁵ found no significant difference in the amounts of cement remnants in the upper or lower jaw. Lang *et al.*³⁸ reported that jaw location wasn't associated with prosthetically related complications, including cement remnants. Therefore, unlike early implant failures discussed by Chrcanovic *et al.*,³⁹ prosthetic-related implant failures did not show any relation to jaw location.

Most of the included studies were *in vitro*, so the lack of clinical studies is one of the limitations of this study. More studies must be done using the same removal and detection method at different marginal abutment levels, focusing on clinical situations and randomized clinical studies. Another limitation of this study is the restoration types of dental implants, as they were all single units. Other types of restorations must be included in studies and future systematic reviews. Increasing the sample size of studies affects the meta-analysis and should be considered in future studies.

CONCLUSION

Our study indicated that:

1. Subgingivally placed marginal levels of the abutment lead to more cement remnants.
2. Placing the marginal level more than 2mm subgingivally makes cleaning almost impossible, especially with resin cement.
3. Clinical studies reported more residual cement than *in vitro* ones, which could be related to the differences between gingival masks and gingiva.
4. Implant position, whether in the maxilla or mandible, had no relation to the amount of cement remnants.

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